



US009472969B2

(12) **United States Patent**
Kaizo et al.

(10) **Patent No.:** **US 9,472,969 B2**
(45) **Date of Patent:** **Oct. 18, 2016**

(54) **ADAPTER AND ELECTRIC POWER TOOL**

2001/0028571 A1* 10/2001 Hanada H02H 9/001

(71) Applicant: **Panasonic Corporation**, Osaka (JP)

2009/0108806 A1* 4/2009 Takano B25F 5/02
320/112

(72) Inventors: **Hiroyuki Kaizo**, Kyoto (JP); **Tadashi Arimura**, Kyoto (JP); **Toshiharu Ohashi**, Shiga (JP)

2010/0213897 A1 8/2010 Tse
2012/0262035 A1 10/2012 Takano et al.

(Continued)

(73) Assignee: **Panasonic Intellectual Property Management Co., Ltd.**, Osaka (JP)

FOREIGN PATENT DOCUMENTS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 379 days.

CN 101154820 4/2008
JP 2002-112465 4/2002

(Continued)

(21) Appl. No.: **13/962,356**

OTHER PUBLICATIONS

(22) Filed: **Aug. 8, 2013**

Chinese Office Action dated Apr. 3, 2015, including Search Report, issued in corresponding Chinese Patent Application No. 201310347179.3 and English translation thereof.

(65) **Prior Publication Data**

(Continued)

US 2014/0042981 A1 Feb. 13, 2014

(30) **Foreign Application Priority Data**

Primary Examiner — Nha Nguyen

Aug. 9, 2012 (JP) 2012-176930

(74) *Attorney, Agent, or Firm* — Renner, Otto, Boisselle & Sklar, LLP

(51) **Int. Cl.**

(57) **ABSTRACT**

H02J 7/00 (2006.01)
H02M 3/156 (2006.01)

An adapter includes a converter unit which increases at least one of voltage and current outputted from a battery pack and supply the increased voltage and/or the current to a load, and a characteristic detection unit which detects at least one of the voltage outputted from the battery pack, the current outputted from the battery pack, a temperature of the battery pack, a voltage inputted to the load, a current inputted to the load and a temperature of the converter unit. The adapter further includes a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and perform a control operation of suppressing such increase to prevent an occurrence of over-current or over-discharge based on at least one detection result.

(52) **U.S. Cl.**

CPC **H02J 7/007** (2013.01); **H02J 7/0065** (2013.01); **H02J 2007/004** (2013.01); **H02J 2007/0039** (2013.01); **H02M 3/156** (2013.01)

(58) **Field of Classification Search**

CPC .. **H02J 7/007**; **H02J 7/0065**; **H02J 2007/004**; **H02J 2007/0039**; **H02M 3/156**; **H01M 2/1033**

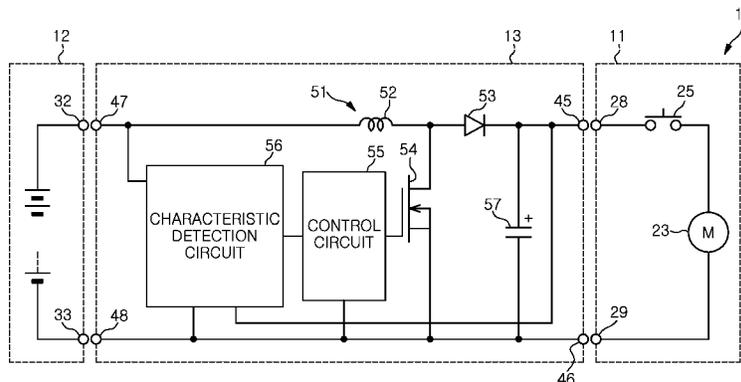
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,075,346 A 6/2000 Kikuchi et al.
8,237,404 B2 8/2012 Takano et al.

18 Claims, 15 Drawing Sheets



(56)

References Cited

WO 2012/056672 A2 5/2012

U.S. PATENT DOCUMENTS

2013/0038289 A1 2/2013 Tse
2013/0154584 A1 6/2013 Sakaue et al.

FOREIGN PATENT DOCUMENTS

JP 2003-219510 7/2003
JP 2008-178278 7/2008
JP 2011-20187 2/2011
JP 2011-161545 8/2011
JP 2011-205866 10/2011
JP 2012-035349 2/2012
WO 2011/103469 8/2011
WO WO2012/096199 * 1/2012

OTHER PUBLICATIONS

Chinese Office Action dated Dec. 3, 2015, including search report, issued in corresponding Chinese Patent Application No. 201310347179.3 and English translation thereof.

Japanese Office Action dated Jan. 19, 2016 issued in corresponding Japanese Patent Application No. 2012-176930 and English summary thereof.

Chinese Office Action dated Jun. 2, 2016 issued in corresponding Chinese Patent Application No. 201310347179.3 and English translation thereof.

Extended European Search Report dated Jul. 1, 2016 issued in corresponding European Patent Application No. 13179822.5.

* cited by examiner

FIG. 1

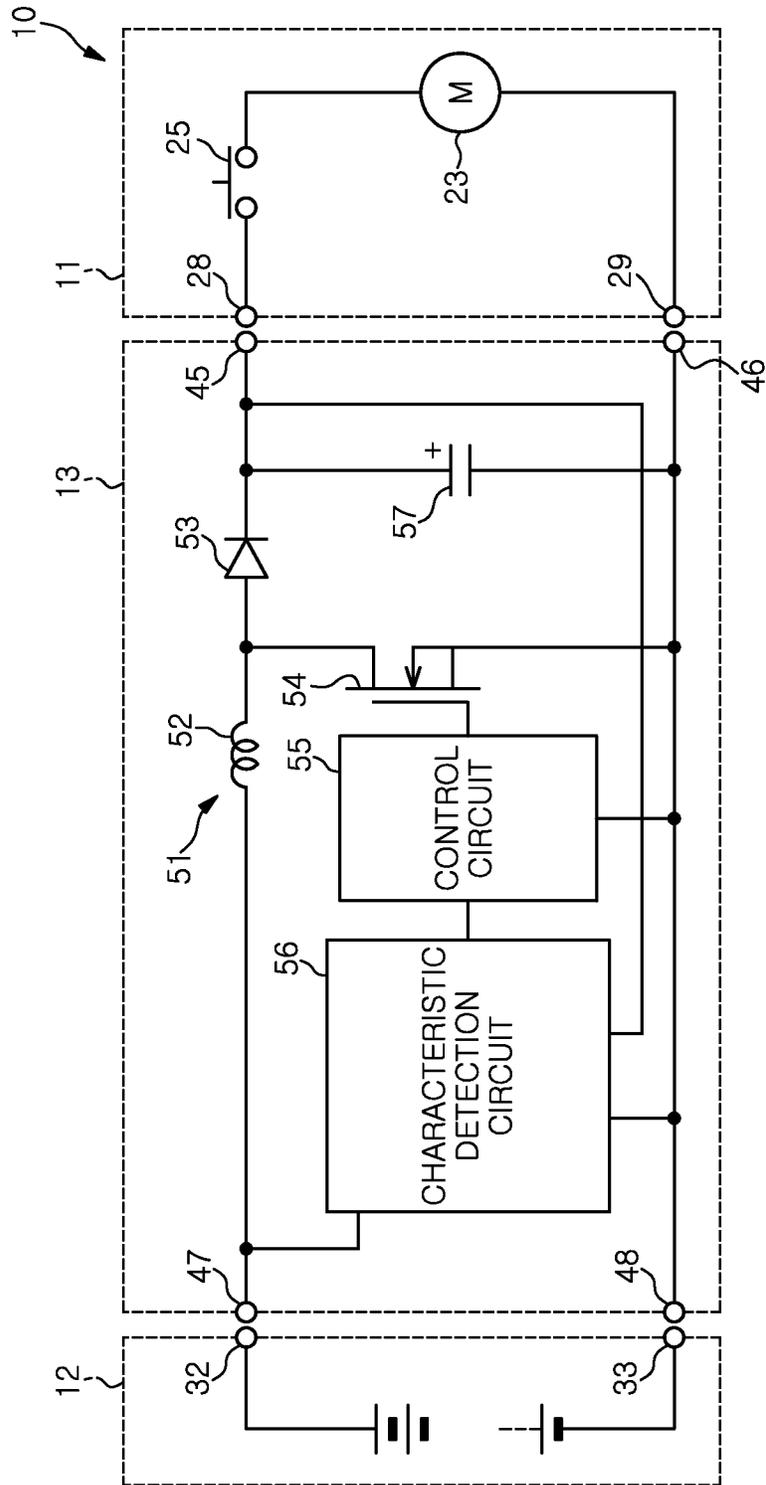


FIG. 2

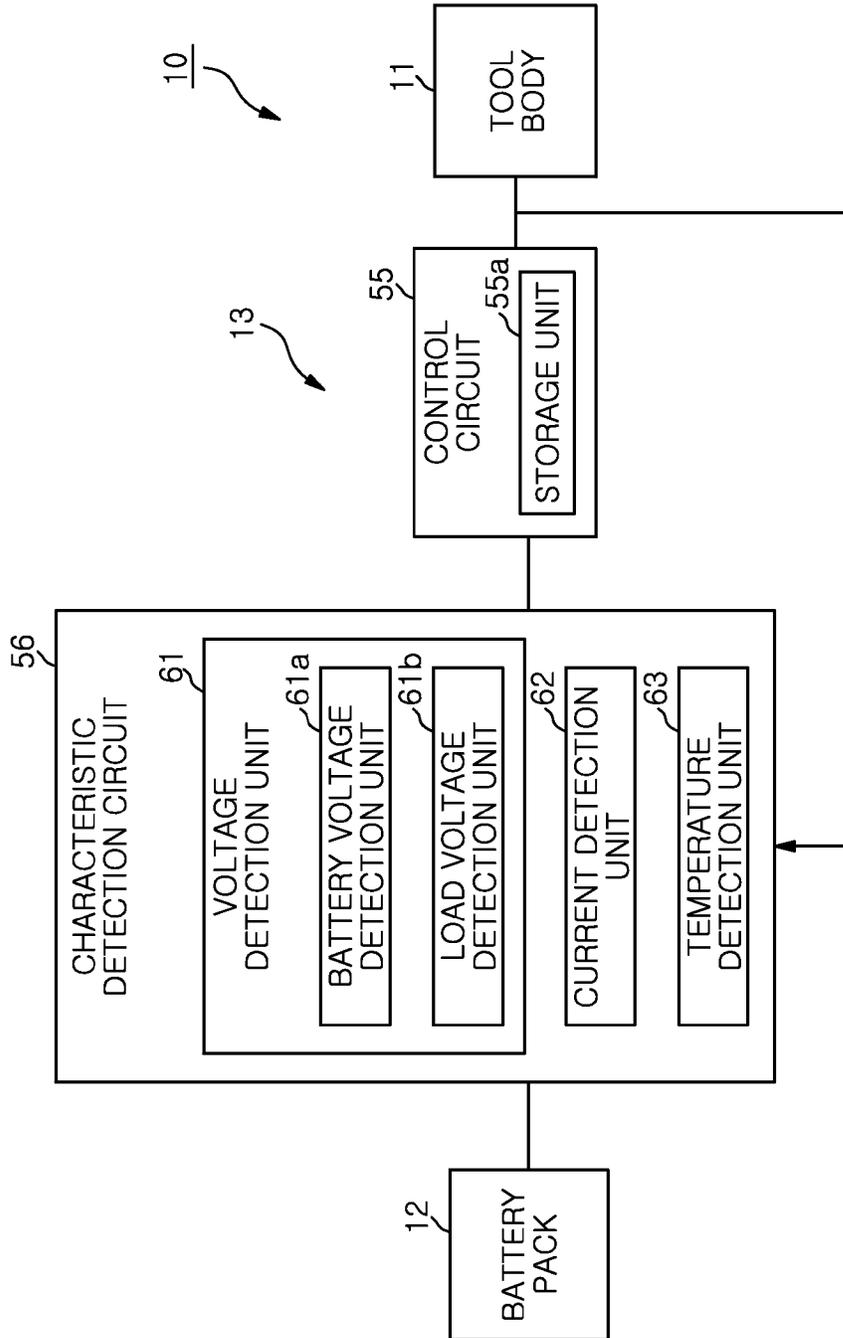


FIG. 3

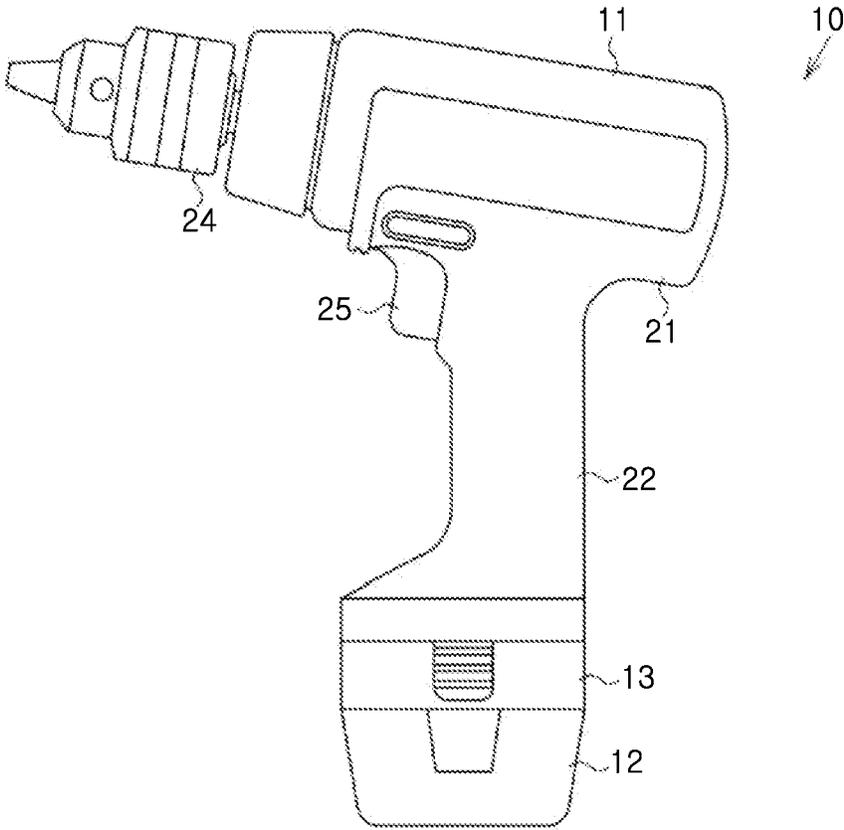


FIG. 4

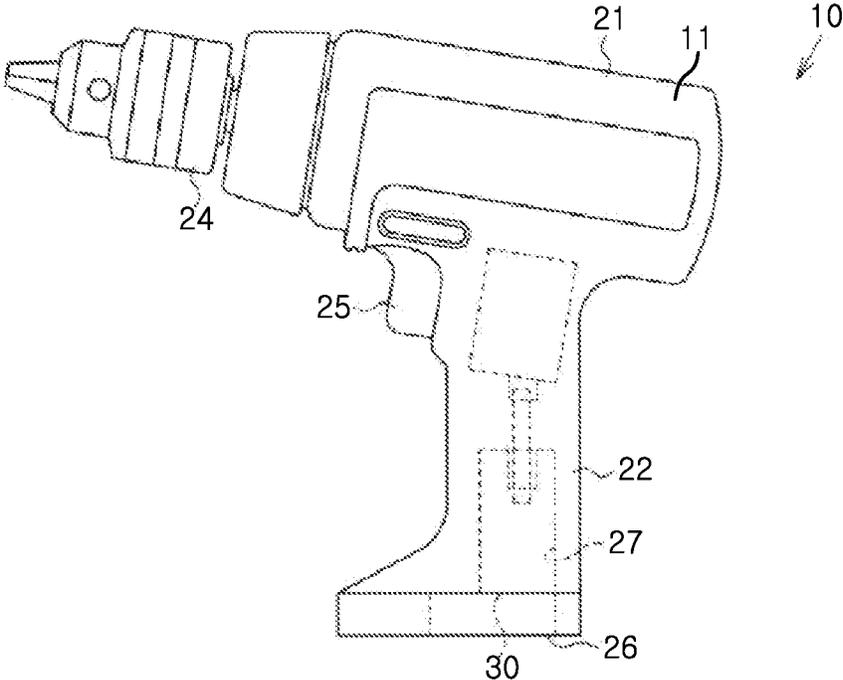


FIG. 5

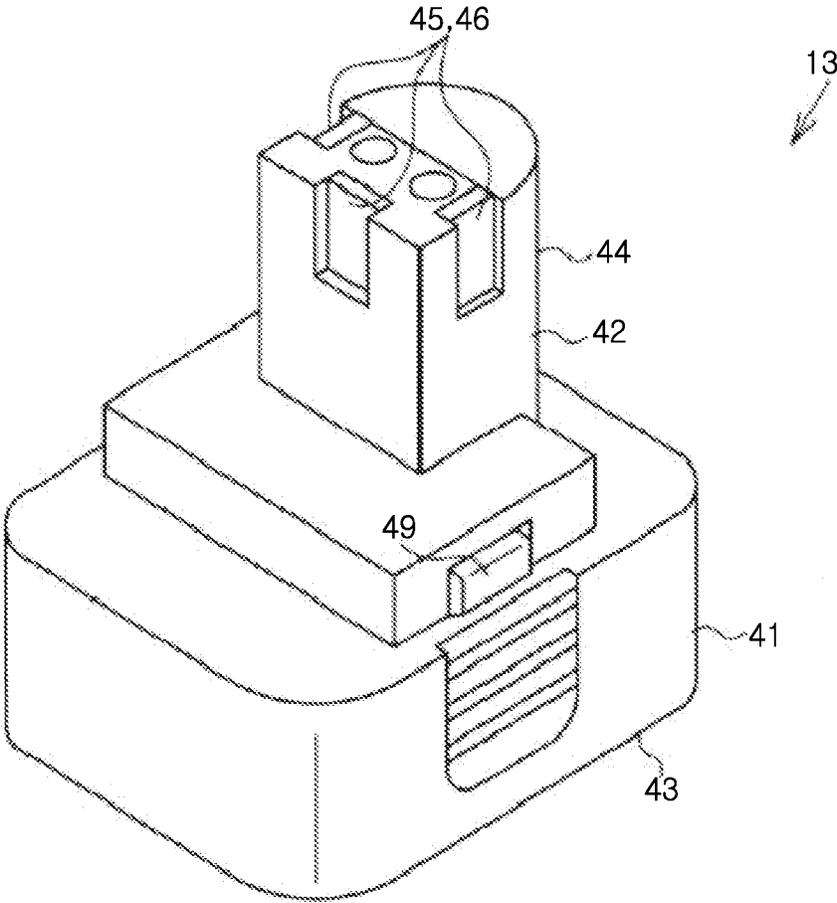


FIG. 6

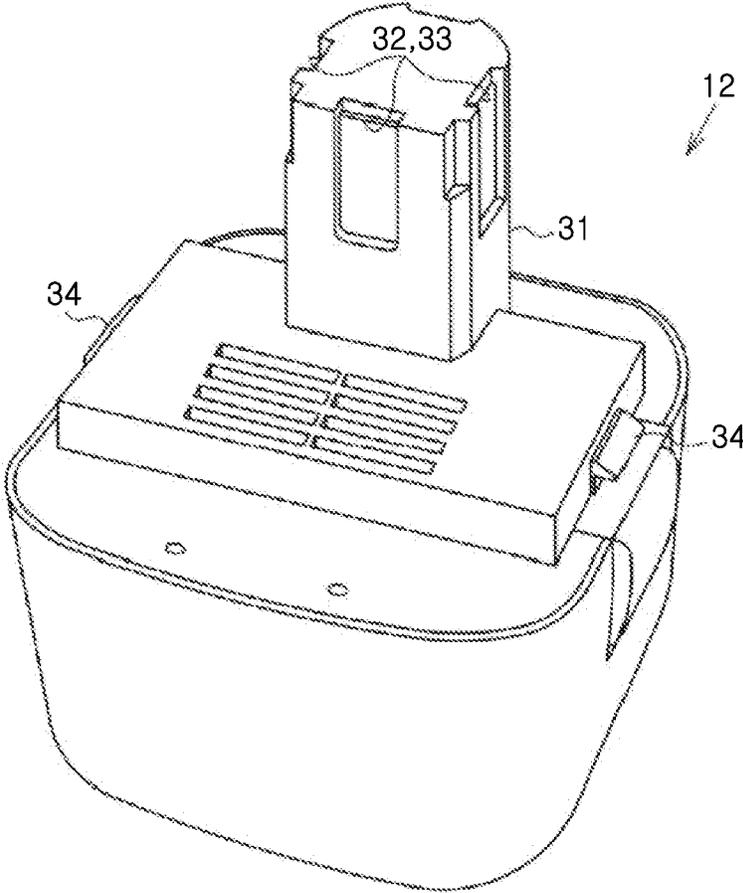


FIG. 7

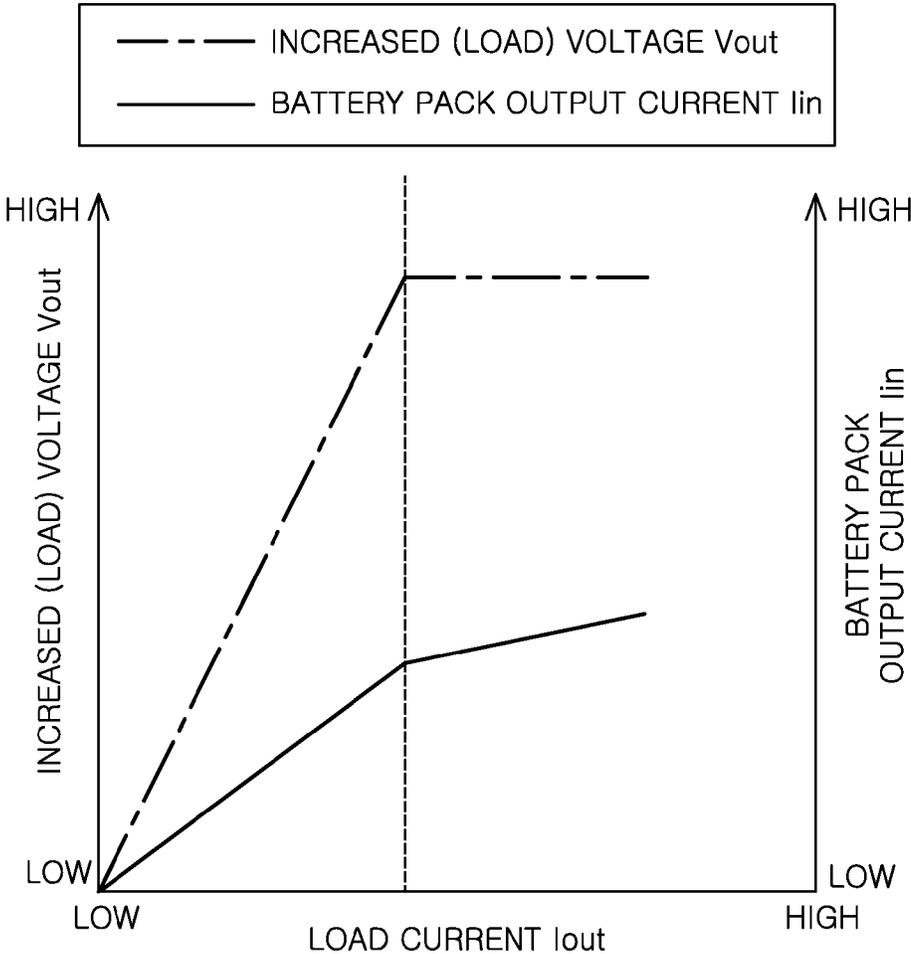


FIG. 8

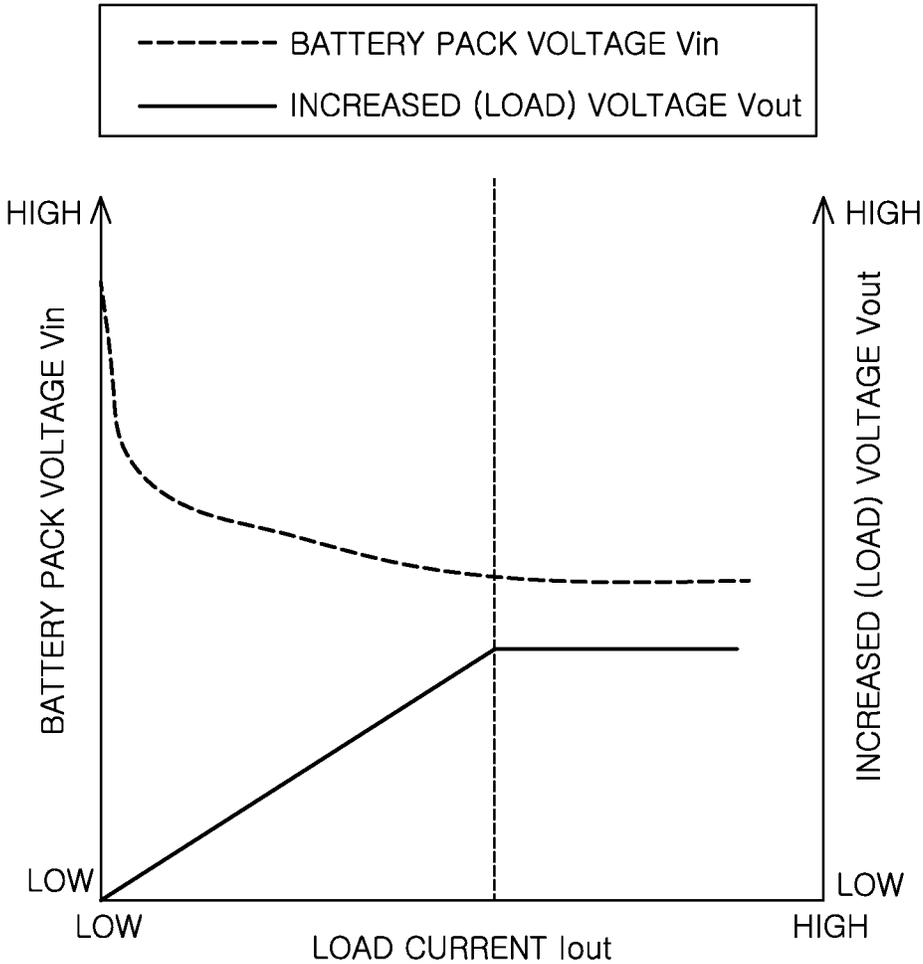


FIG. 9

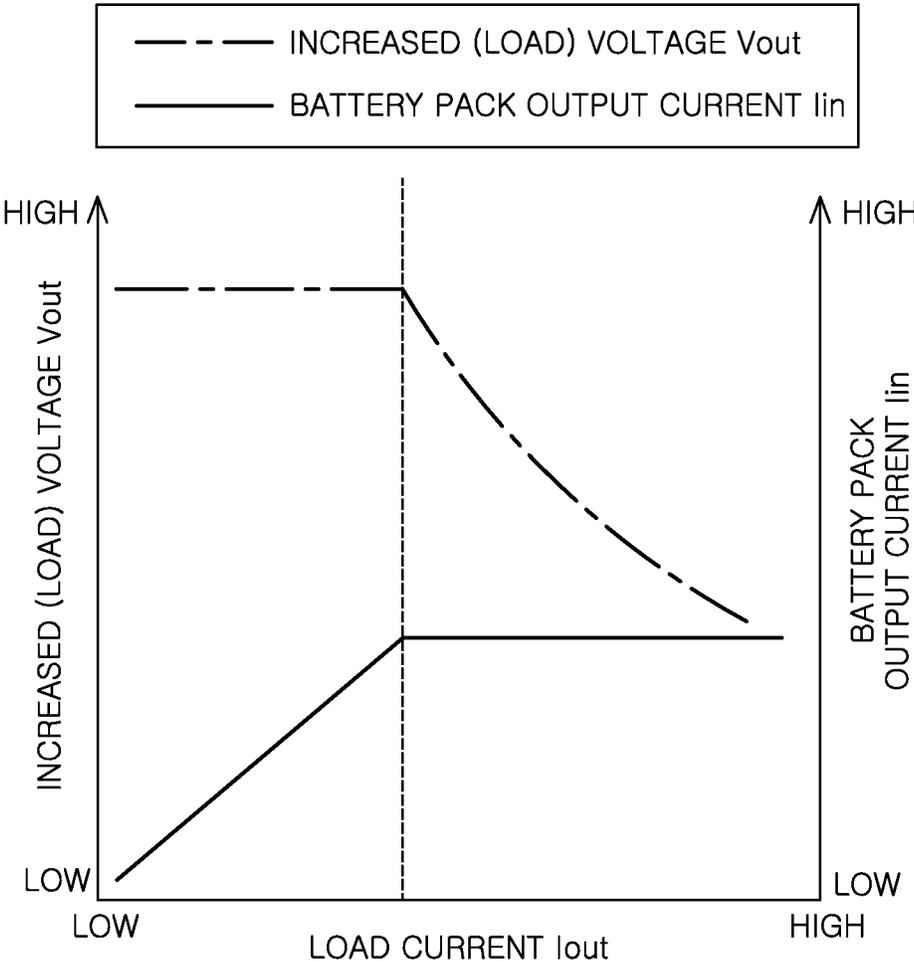


FIG. 10

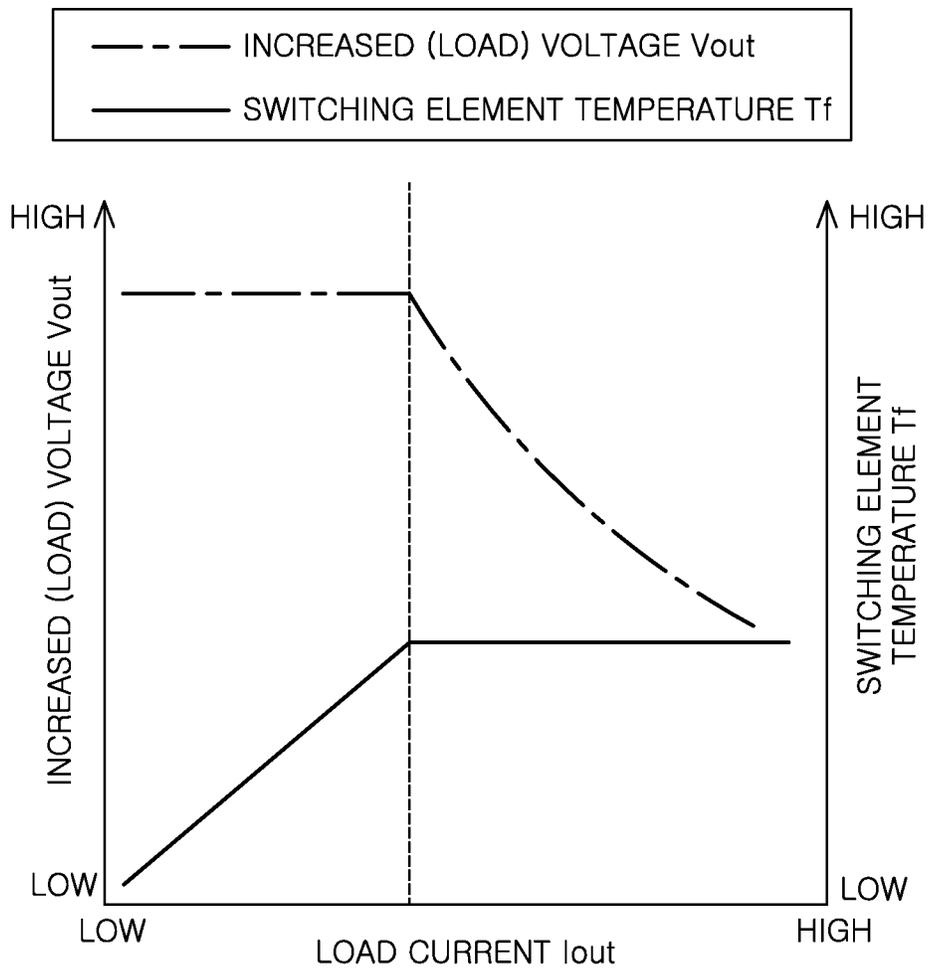


FIG. 11

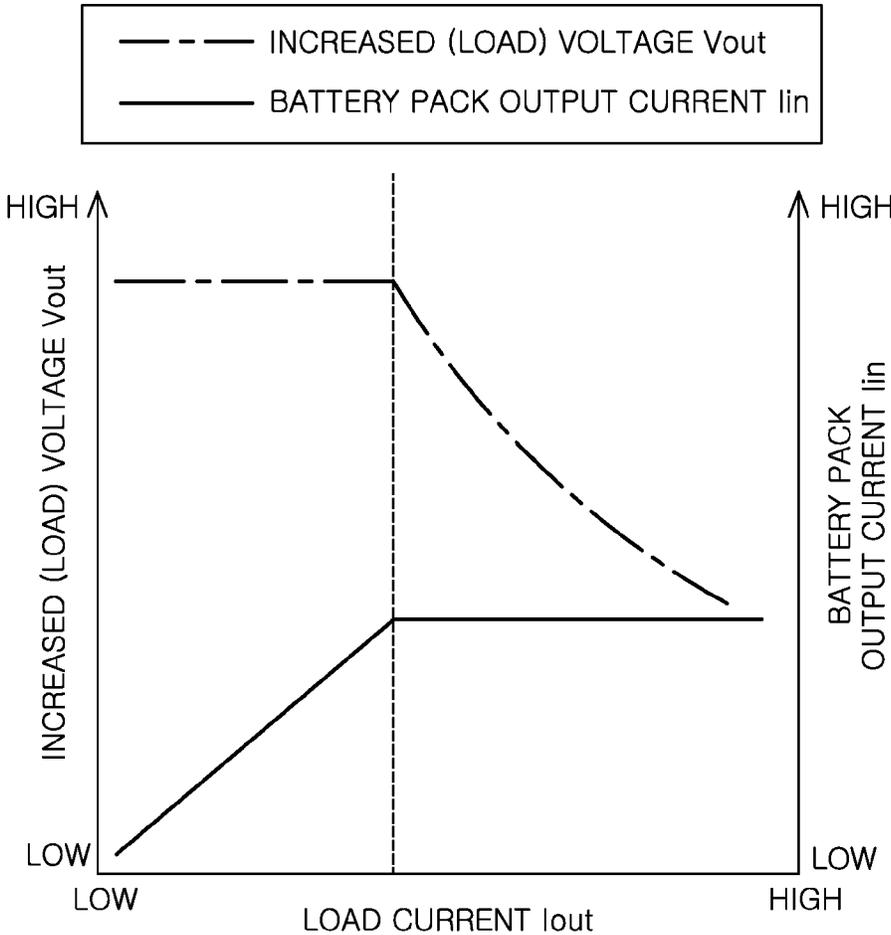


FIG. 12

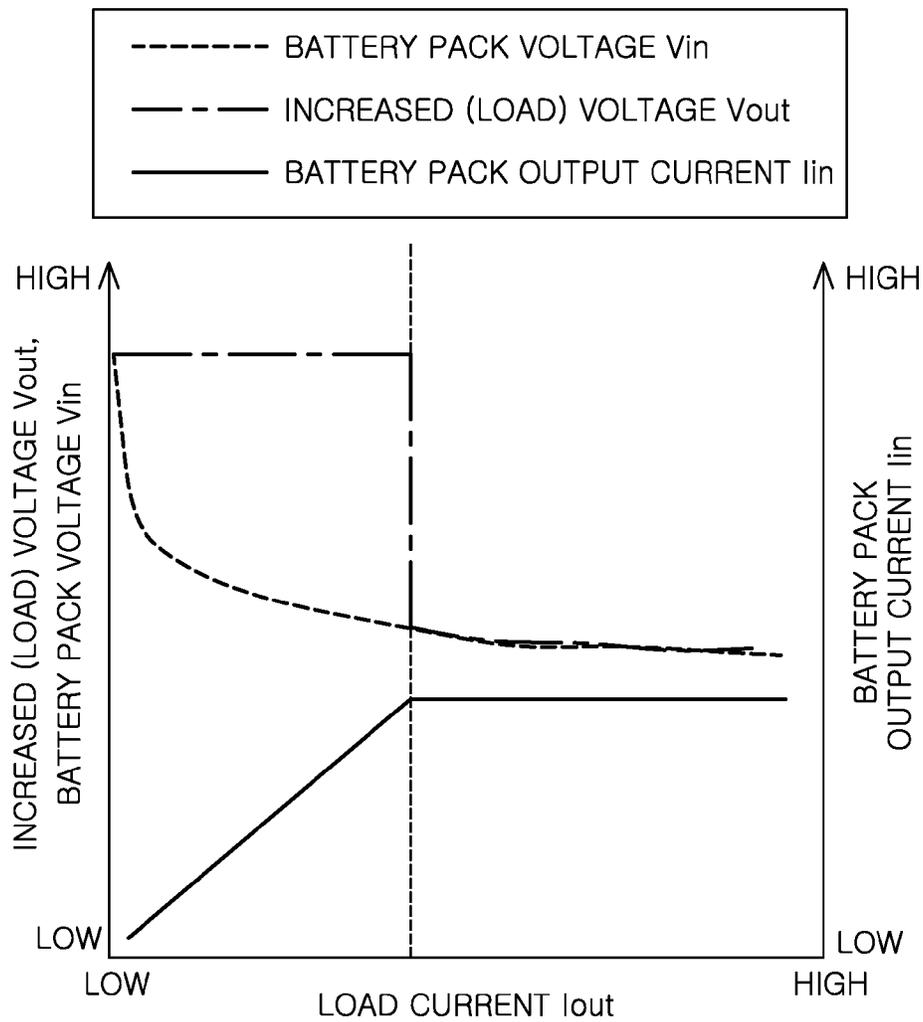


FIG. 13

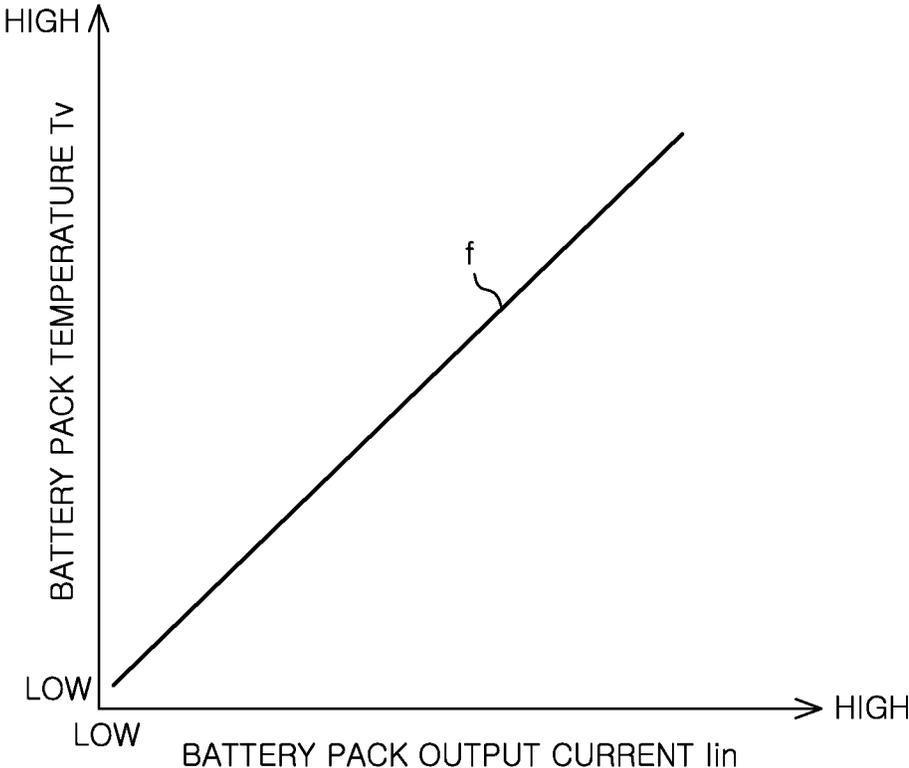


FIG. 14

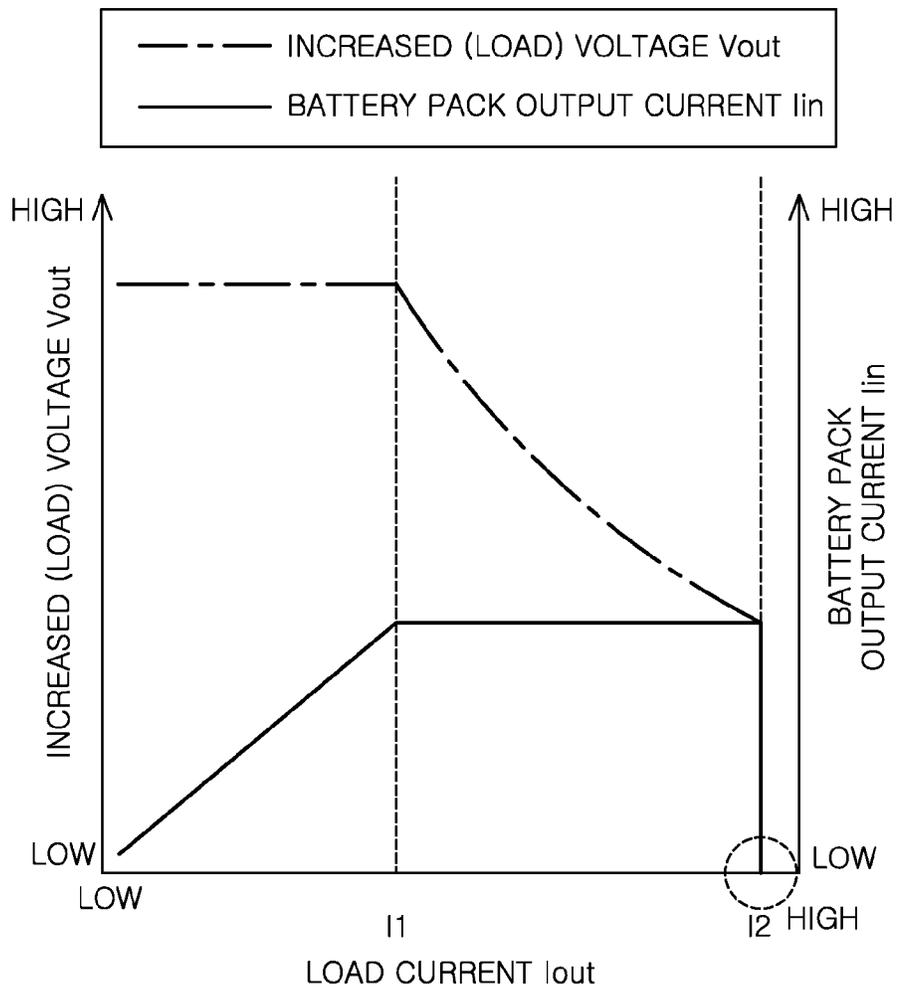
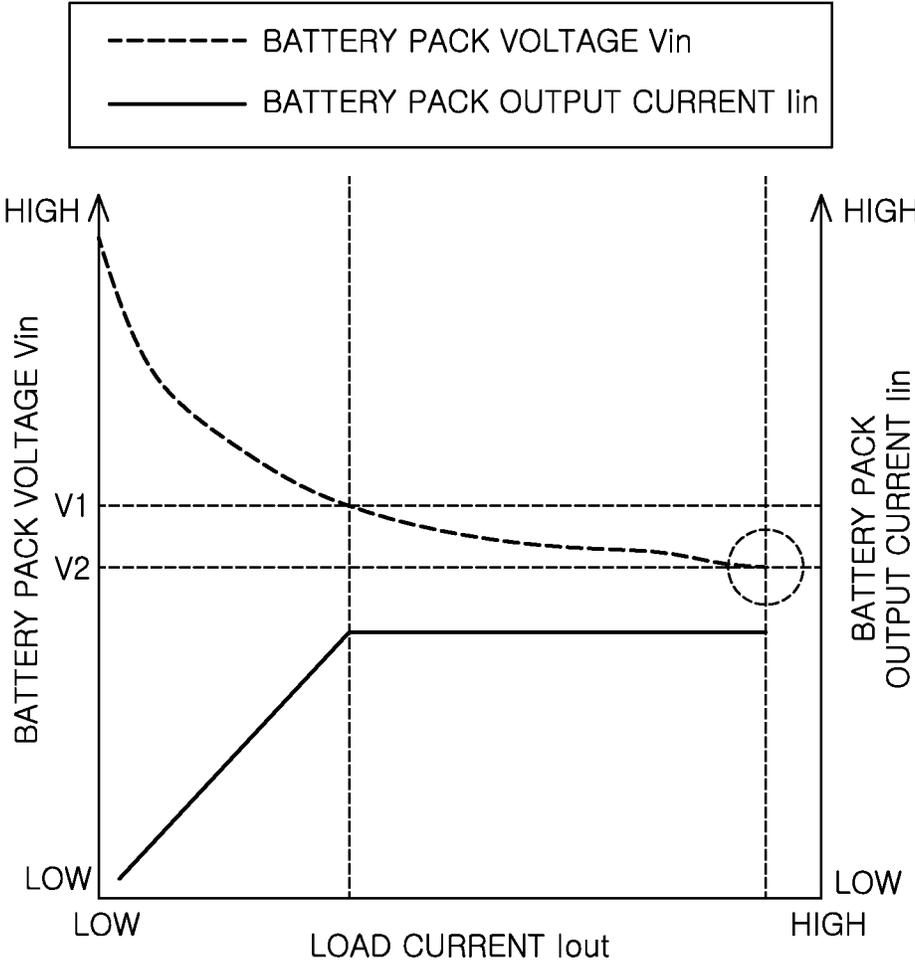


FIG. 15



1

ADAPTER AND ELECTRIC POWER TOOL

FIELD OF THE INVENTION

The present invention relates to an adapter and an electric power tool.

BACKGROUND OF THE INVENTION

Conventionally, there is known an electric power tool in which an adapter capable of mounting a battery pack having a different rated voltage is provided between a tool body and the battery pack. In an electric power tool described in, e.g., Japanese Patent Application Publication No. 2012-35349, an adapter is provided with a converter circuit. Even when a battery pack having a different rated voltage is used, the electric power supplied to the tool body is adjusted by controlling the electric power (voltage) supplied from the battery pack (power source), that is by performing a step-up or step-down operation with the converter circuit.

In the electric power tool which employs the adapter provided with the converter circuit, there is a need to increase (step up) the battery pack voltage so as to become a rated voltage. When the step-up operation is continuously performed in a state that a work load remains high, there may occur over-current. Possibly, the battery pack may be heated and may be out of order. In view of this, when the over-current or over-discharge is likely to occur, it is considered to cut off the electric power supplied to a load (a motor in case of the electric power tool), thereby stopping the operation of the load. However, such stoppage of the operation of the load may worsen the workability of a user who makes use of the electric power tool.

This holds true in an electric power tool in which a converter circuit as a component of an adapter is provided in a tool body, i.e., an electric power tool having a built-in adapter.

SUMMARY OF THE INVENTION

In view of the above, the present invention provides an adapter and an electric power tool capable of suppressing an occurrence of over-current or over-discharge while maintaining workability.

In accordance with an embodiment of the present invention, there is provided an adapter including: a converter unit configured to increase at least one of a voltage and a current outputted from a battery pack and supply the increased at least one of the voltage and the current to a load; a characteristic detection unit configured to detect at least one of the voltage outputted from the battery pack, the current outputted from the battery pack, a temperature of the battery pack, a voltage inputted to the load, a current inputted to the load and a temperature of the converter unit; and a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and further perform a control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent an occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection unit.

Further, the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit within a range equal to or smaller than the corresponding reference value to

2

prevent the occurrence of over-current or over-discharge based on said at least one detection result.

Further, the characteristic detection unit may be configured to detect the voltage inputted to the load, and the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current or over-discharge based on the detected voltage.

Further, the characteristic detection unit may be configured to detect the voltage outputted from the battery pack, and the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current or over-discharge based on the detected voltage.

Further, the characteristic detection unit may be configured to detect one of the current inputted to the load and the current outputted from the battery pack, and the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current or over-discharge based on the detected current.

Further, the characteristic detection unit may be configured to detect one of the temperature of the battery pack and the temperature of the converter unit, and the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current or over-discharge based on the detected temperature.

Further, the characteristic detection unit may be configured to detect at least two of the voltage outputted from the battery pack, the current outputted from the battery pack, the temperature of the battery pack, the voltage inputted to the load, the current inputted to the load and the temperature of the converter unit, and the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current or over-discharge based on at least two detection results detected by the characteristic detection unit.

Further, the characteristic detection unit is configured to detect one of the current outputted from the battery pack and the current inputted to the load, and one of the voltage outputted from the battery pack and the voltage inputted to the load, and when the detected current reaches a reference current value and the detected voltage becomes equal to or smaller than a reference voltage value, the control unit may stop the converter unit and allow the voltage supplied from the battery pack to be supplied to the load.

Further, the adapter described above may further include a storage unit in which temperatures of the battery pack and reference currents corresponding to the temperatures of the battery pack are stored. The characteristic detection unit may be configured to detect the temperature of the battery pack and the current outputted from the battery pack, and by referring to a reference current corresponding to the detected temperature of the battery pack, the control unit may compare the detected current with the reference current, and perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit when the detected current is higher than the reference current.

Further, the control unit may have a first over-current threshold and a second over-current threshold larger than the first over-current threshold. When a detection result reaches the first over-current threshold, the control unit may perform

3

the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current, and when the detection result reaches the second over-current threshold, the control unit may stop the operation of the load.

Further, the control unit may have a first over-discharge threshold and a second over-discharge threshold smaller than the first over-discharge threshold. When a detection result reaches the first over-discharge threshold, the control unit may perform the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-discharge, and when the detection result reaches the second over-discharge threshold, the control unit may stop the operation of the load.

In accordance with another embodiment of the present invention, there is provided an electric power tool including: the adapter described in any one of claims 1 to 11; the battery pack; and a tool body having the load.

Further, the adapter may be configured to be provided in the tool body.

Further, the adapter may be configured to be provided between the tool body and the battery pack.

In accordance with the present invention, it is possible for the adapter and the electric power tool to suppress the occurrence of over-current or over-discharge while maintaining workability.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the present invention will become apparent from the following description of embodiments, given in conjunction with the accompanying drawings, in which:

FIG. 1 is a circuit diagram for explaining a schematic configuration of an electric power tool in accordance with an embodiment;

FIG. 2 is a block diagram for explaining the schematic configuration of the electric power tool in accordance with the embodiment;

FIG. 3 shows the schematic configuration of the electric power tool in accordance with the embodiment;

FIG. 4 shows the schematic configuration of a tool body making up the electric power tool in accordance with the embodiment;

FIG. 5 is a perspective view of an adapter making up the electric power tool in accordance with the embodiment;

FIG. 6 is a perspective view of a battery pack making up the electric power tool in accordance with the embodiment;

FIG. 7 is a graph for explaining an operation example of the electric power tool in accordance with the embodiment; and

FIGS. 8 to 15 are graphs for explaining other operation examples of the electric power tool, respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described with reference to embodiments shown in the accompanying drawings which form a part hereof.

Hereinafter, an electric power tool provided with an adapter in accordance with an embodiment of the present invention will now be described with reference to the accompanying drawings, which form a part hereof.

4

As shown in FIGS. 1 and 3, the electric power tool 10 of the present embodiment includes a tool body 11, a battery pack 12 and an adapter 13 arranged between the tool body 11 and the battery pack 12.

Referring to FIG. 4, the tool body 11 includes a substantially tubular housing 21 and a handle 22 extending laterally (downwardly) from the housing 21. As illustrated in FIGS. 1 and 4, a motor 23 serving as a load is accommodated in the housing 21 of the tool body 11. The motor 23 is connected to a reduction gear mechanism (not shown) formed of a plurality of gear trains. The drive power of the motor 23 is transmitted to an output unit 24 of the tool body 11 via the reduction gear mechanism. The output unit 24 is rotatably arranged at the tip end of the housing 21. A front end tool (e.g., a driver bit or the like) is detachably attached to the tip end of the output unit 24.

As illustrated in FIGS. 1 and 4, the handle 22 is provided with a trigger switch 25, which is configured to instruct the operation and stop of the electric power tool 10. The trigger switch 25 is configured to control the rotation speed of the motor 23 by controlling the supply of electric power to the motor 23 according to adjustment of the push-in amount of the trigger switch 25.

The tool body 11 is provided with a mounting portion 26 for mounting the adapter 13 or the battery pack 12 at a lower end of the handle 22. One of the adapter 13 and the battery pack 12 is selectively mounted to the mounting portion 26. In the present embodiment, the mounting portion 26 is a so-called a plug-in type mounting portion 26 which includes a recess portion 27 formed on the lower end surface of the handle 22 and terminals arranged on the inner-side surface of the recess portion 27.

As shown in FIG. 1, the terminals of the mounting portion 26 include a first tool-side terminal 28 connected to a positive electrode of the battery pack 12 and a second tool-side terminal 29 connected to a negative electrode of the battery pack 12. The mounting portion 26 further includes a pair of engaged portions 30, which is configured to be engaged with a pair of engagement portions 49 of the adapter 13 or a pair of engagement portions 34 of the battery pack 12.

With such configuration, when a plug-in protrusion portion 44 of the adapter 13 or a plug-in protrusion portion of the battery pack 12 is inserted to a specified position, the engaged portions 30 prevent removal of the adapter 13 or the battery pack 12. Upon inserting the adapter 13 or the battery pack 12 to the specified position, the engaged portions 30 of the mounting portion 26 is engaged with the engagement portions 49 or the engagement portions 34, so that the first tool-side terminal 28 and the second tool-side terminal 29 of the mounting portion 26 come into contact with, and are electrically connected to, terminals 45 and 46 of the adapter 13 or the terminals 32 and 33 of the battery pack 12.

As shown in FIG. 6, the battery pack 12 includes the plug-in protrusion portion 31 protruding upward. The plug-in protrusion portion 31 has the terminals 32 and 33 at its tip end. As depicted in FIG. 1, the terminals 32 and 33 are composed of a first power-source side terminal 32 on the positive electrode side and a second power-source side terminal 33 on the negative electrode side. The battery pack 12 includes a built-in rechargeable battery, and an example of the rechargeable battery includes a secondary battery such as a lithium-ion battery or the like. In the present embodiment, there are provided different types of battery packs 12, and voltages thereof are different from each other.

All the battery packs 12 of the present embodiment have the plug-in protrusion portion 31 of identical shape. Thus,

the battery packs **12** are mounted in the same manner. The battery packs **12** are not limited to the plug-in type. As an alternative example, the battery packs **12** may be configured to be detachably attached to the lower surface of the handle **22** of the tool body **11** by sliding the battery packs **12** in the direction substantially orthogonal to the extension direction of the handle **22**.

The adapter **13** is configured to be detachably mounted between the tool body **11** and the battery pack **12**. The adapter **13** is configured to convert the voltage of the battery pack **12** to the rated voltage of the tool body **11**.

As shown in FIG. 5, the adapter **13** includes an adapter body **41**, a tool connection portion **42** to be connected to the tool body **11** and a battery connection portion **43** to be connected to the battery pack **12**.

The tool connection portion **42** is composed of a plug-in protrusion portion **44** protruding from one end surface (an upper surface) of the adapter body **41**. The plug-in protrusion portion **44** is fitted into the recess portion **27** of the handle **22** of the tool body **11**. The plug-in protrusion portion **44** has, at its tip end, output-side terminals **45** and **46**, which are electrically connected to the terminals of the tool body **11**. The output-side terminals **45** and **46** include a first output-side terminal **45** to be connected to the first tool-side terminal **28** and a second output-side terminal **46** to be connected to the second tool-side terminal **29**.

The battery connection portion **43** is arranged on the other end surface (a lower surface) of the adapter body **41**. The battery connection portion **43** is composed of a plug-in recess portion (not shown) into which the plug-in protrusion portion **31** of the battery pack **12** can be inserted. The plug-in recess portion has, on its inner-side surface, input-side terminals **47** and **48**, which are electrically connected to the terminals of the battery pack **12**. The input-side terminals **47** and **48** include a first input-side terminal **47** to be connected to the first power-source side terminal **32** and a second input-side terminal **48** to be connected to the second power-source side terminal **33**.

The adapter **13** includes a converter circuit **51** configured to increase (step-up) the voltage of the battery pack **12** to convert the voltage of the battery pack **12** into the rated voltage of the tool body **11**.

As shown in FIG. 1, the converter circuit **51** includes a coil **52** and a diode **53** serially connected between the first input-side terminal **47** and the first output-side terminal **45**. The converter circuit **51** further includes a switching element (FET) **54** connected between the coil **52** and the second input-side terminal **48**. A control circuit **55** is connected to the gate of the switching element **54**. The ON/OFF operation of the switching element **54** is controlled by the control circuit **55**. Connected to the output side of the adapter **13** is a characteristic detection circuit **56**, which is configured to detect at least one of a voltage outputted from the battery pack **12**, a current outputted from the battery pack **12**, a temperature of the battery pack **12**, a voltage inputted to the load (motor) **23**, a current inputted to the load **23** and a temperature of the converter circuit (the converter unit) **51**. Based on a detection value detected by the characteristic detection circuit **56**, the control circuit **55** controls the ON/OFF operation and the duty ratio of the switching element **54**. The converter circuit **51** further includes a smoothing capacitor **57** connected to the output side of the adapter **13**.

As shown in FIG. 2, the characteristic detection circuit **56** may include a voltage detection unit **61** and a current detection unit **62**. The voltage detection unit **61** may include a battery voltage detection unit **61a** configured to detect a

voltage V_{in} between the first input-side terminal **47** and the second input-side terminal **48** as a voltage of the battery pack **12**, and a load voltage detection unit **61b** configured to detect a voltage V_{out} between the first output-side terminal **45** and the second output-side terminal **46** as a load voltage. The current detection unit **62** detects a current I_{in} flowing between the first input-side terminal **47** and the coil **52** as a current outputted from the battery pack **12** and detects an output current I_{out} flowing between the diode **53** and the first output-side terminal **45** as a current outputted to the load (motor) **23**.

As shown in FIGS. 1 and 2, the control circuit **55** controls the ON/OFF operation and the duty ratio of the switching element **54** such that detection results (here, detection voltage and current) have values corresponding to the specified voltage and current of the tool body **11**. The control circuit **55** controls the switching element **54** so as to repeat the ON/OFF operation, thereby storing electromagnetic energy in the coil **52**. At a moment when a specified amount of energy is stored in the coil **52**, the control circuit **55** controls the switching element **54** such that the switching element **54** is turned off. As a result, the electromagnetic energy stored in the coil **52** is discharged, and the output voltage of the adapter **13** is thereby increased. The voltage thus increased is applied to the tool body **11** (the motor **23**).

Next, an operation example of the electric power tool in accordance with the present embodiment will be described with reference to FIG. 7.

When the trigger switch **25** of the tool body **11** is pushed inward, the electric power begins to be supplied from the battery pack **12**. The control circuit **55** performs a PWM-control of the switching element **54** in the converter circuit **51**, thereby causing the converter circuit **51** to start a convert control (e.g., an increase of voltage or current). At this time, the control circuit **55** monitors, through the characteristic detection circuit **56**, the increased voltage (the load voltage) V_{out} , the current (the load current) I_{out} outputted to the load and the current I_{in} outputted from the battery pack **12**. When the load voltage V_{out} reaches a value suitable for use in the tool body **11** (the rated voltage in case of the present embodiment), the control circuit **55** controls at least one of the current and the voltage so that the load voltage V_{out} does not exceed the rated voltage of the tool body **11**. For example, the current I_{in} outputted from the battery pack **12** is reduced (that is, an increase rate of the current I_{in} with respect to the load current I_{out} becomes lowered as shown in FIG. 7), so that it is possible to suppress the occurrence of over-current with respect to the battery pack **12**.

Next, description will be made on the effects provided by the present embodiment.

(1) The control circuit **55** of the adapter **13** controls the converter circuit **51** to increase each of at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and also performs a control operation of suppressing the increase of at least one of the voltage and the current in the converter circuit to prevent the occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection circuit **56**. In this regard, the electric power is continuously supplied to the motor **23** while the increase of at least one of the voltage and the current is suppressed. It is therefore possible to suppress the occurrence of over-current or over-discharge while maintaining workability.

(2) The control circuit **55** performs the control operation of suppressing the increase of at least one of the voltage and the current within a range equal to or smaller than the reference value (e.g., the rated voltage) to prevent the

occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection circuit 56. Accordingly, it becomes possible to reliably suppress the occurrence of over-current or over-discharge.

(3) The characteristic detection circuit 56 detects the voltage inputted to the motor 23. The control circuit 55 performs the control operation of suppressing the increase of at least one of the voltage and the current in the converter circuit 51 to prevent the occurrence of over-current or over-discharge based on the voltage value detected by the characteristic detection circuit 56. Since such control operation is performed while the electric power is continuously supplied to the motor 23, it is possible to suppress the occurrence of over-current or over-discharge while maintaining workability.

Various modification can be made to the embodiment of the present invention as described below.

For example, as shown in FIG. 8, the control circuit 55 monitors the voltage V_{in} outputted from the battery pack through the characteristic detection circuit 56, and suppresses the increase of, e.g., the load voltage V_{out} , by controlling at least one of the current and the voltage such that the voltage V_{in} of the battery pack 12 does not become equal to or smaller than a reference value. Accordingly, it is possible to suppress the occurrence of the over-discharge with respect to the battery pack 12.

For example, as shown in FIG. 9, the control circuit 55 monitors the current I_{in} outputted from the battery pack through the characteristic detection circuit 56, and reduces, e.g., the increased voltage, by performing a PWM control of the switching element 54 so that, upon reaching a reference value, the current I_{in} outputted from the battery pack 12 is restrained from increasing beyond the reference value. Accordingly, it is possible to suppress the occurrence of over-discharge or over-current with respect to the battery pack 12.

While not specifically described in the foregoing embodiment, it may be possible to employ a configuration in which the characteristic detection circuit 56 may include a temperature detection unit 63 configured to detect a battery pack temperature T_v or a temperature of at least one circuit component of the converter circuit 51 representing a temperature of the converter circuit (converter unit) 51 (e.g., at least one of a characteristic detection circuit temperature T_s , a control circuit temperature T_m , a coil temperature T_l , a diode temperature T_d , a switching element temperature T_f and a capacitor temperature T_c).

For example, as shown in FIG. 10, if it is assumed that the switching element temperature T_f is detected by the temperature detection unit 63 of the characteristic detection circuit 56, the control circuit 55 reduces, e.g., the increased voltage, by performing a PWM control of the switching element 54 so that, upon reaching a reference value, the switching element temperature T_f is restrained from increasing beyond the reference value. Accordingly, it is possible to suppress the occurrence of over-discharge or over-current with respect to the battery pack 12.

Further, for example, the characteristic detection circuit 56 may include at least two of the voltage detection unit 61, the current detection unit 62 and the temperature detection unit 63. Using two or more detection results detected by at least two of the voltage detection unit 61, the current detection unit 62 and the temperature detection unit 63, the control circuit 55 may perform a control operation of suppressing the increase of at least one of the voltage and the current. FIG. 11 illustrates an instance where the battery-

pack output current I_{in} and the load voltage V_{out} are detected by the characteristic detection circuit 56. As illustrated in FIG. 11, the characteristic detection circuit 56 detects the battery-pack output current I_{in} and the load voltage V_{out} . Based on the detection results, the control circuit 55 suppresses the increase of at least one of the current and the voltage. Accordingly, it is possible to suppress the occurrence of over-discharge or over-current with respect to the battery pack 12.

Further, for example, the characteristic detection circuit 56 may include a current detection unit 62 and a temperature detection unit 63. As shown in FIG. 2, the control circuit 55 includes a storage unit 55a which stores a temperature-current conversion table (a function f in FIG. 13) which is a correspondence table between battery pack temperatures T_v and currents I_{in} outputted from the battery pack 12. By referring to the temperature-current conversion table, the control circuit 55 finds a reference current value from the battery pack temperature T_v detected by the temperature detection unit 63. When the current I_{in} detected by the current detection unit 62 is higher than the reference current value, the control circuit 55 performs a control operation of suppressing the increase of at least one of the voltage and the current. While the function f has a direct proportional relationship in FIG. 13, the present invention is not necessarily limited thereto.

Further, for example, as shown in FIG. 12, when the current I_{in} or the current I_{out} detected by the current detection unit 62 reaches a reference current value and when the voltage V_{in} or the voltage V_{out} detected by the characteristic detection circuit 56 becomes equal to or lower than a reference voltage value, the control circuit 55 stops the converter circuit 51 and allows the voltage supplied from the battery pack 12 to be supplied to the motor 23. With this configuration, it is possible to restrain the converter circuit 51 from incurring over-discharge or over-current with respect to the battery pack 12.

For example, as shown in FIG. 14, the control circuit 55 has a first over-current threshold 11 and a second over-current threshold 12 larger than the first over-current threshold 11. When the current I_{in} outputted from the battery pack 12 for example reaches the first over-current threshold 11, the control circuit 55 reduces the load voltage V_{out} by suppressing the increase of at least one of the voltage and the current in the converter circuit 51 to prevent the occurrence of over-current based on the detection result detected by the characteristic detection circuit 56. When the current I_{in} outputted from the battery pack 12 for example reaches the second over-current threshold 12, the control circuit 55 stops the operation of the motor 23. With this configuration, it is possible to prevent the battery pack 12 from being broken.

Further, for example, as shown in FIG. 15, the control circuit 55 has a first over-discharge threshold V_1 and a second over-discharge threshold V_2 smaller than the first over-discharge threshold V_1 . When the voltage V_{in} outputted from the battery pack 12 for example reaches the first over-discharge threshold V_1 , the control circuit 55 reduces the load voltage V_{out} by suppressing the increase of at least one of the voltage and the current in the converter circuit 51 to prevent the occurrence of over-discharge based on the detection result detected by the characteristic detection circuit 56. If the voltage V_{in} outputted from the battery pack 12 for example reaches the second over-discharge threshold V_2 , the control circuit 55 stops the operation of the motor 23. With this configuration, it is possible to prevent the battery pack 12 from being broken.

9

While the electric power tool **10** provided with the adapter **13** is described in the above embodiment, the present invention is not limited thereto. For example, a cleaner, a blower or an illumination device may be provided with the adapter **13**.

While the invention has been shown and described with respect to the embodiments, it will be understood by those skilled in the art that various changes and modification may be made without departing from the scope of the invention as defined in the following claims.

What is claimed is:

1. An adapter, comprising:
 - a converter unit configured to increase at least one of a voltage and a current outputted from a battery pack and supply the increased at least one of the voltage and the current to a load;
 - a characteristic detection unit configured to detect at least one of the voltage outputted from the battery pack, the current outputted from the battery pack, and a temperature of the battery pack;
 - a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and further perform a control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent an occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection unit while continuously supplying the increased at least one of the voltage and the current to the load; and
 - a storage unit in which temperatures of the battery pack and reference currents corresponding to the temperatures of the battery pack are stored,
 wherein the characteristic detection unit is configured to detect the temperature of the battery pack and the current outputted from the battery pack, and
 - wherein, by referring to a reference current corresponding to the detected temperature of the battery pack, the control unit compares the detected current with the reference current, and, when the detected current is higher than the reference current, performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit while continuously supplying the increased at least one of the voltage and the current to the load.
2. An electric power tool comprising:
 - the adapter described in claim **1**;
 - the battery pack; and
 - a tool body having the load.
3. The electric power tool of claim **2**, wherein the adapter is configured to be provided in the tool body.
4. The electric power tool of claim **2**, wherein the adapter is configured to be provided between the tool body and the battery pack.
5. An adapter, comprising:
 - a converter unit configured to increase at least one of a voltage and a current outputted from a battery pack and supply the increased at least one of the voltage and the current to a load;
 - a characteristic detection unit configured to detect at least one of the voltage outputted from the battery pack, the current outputted from the battery pack, and a temperature of the battery pack; and
 - a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corre-

10

- sponding reference value and further perform a control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent an occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection unit while continuously supplying the increased at least one of the voltage and the current to the load,
 - wherein the control unit has a first over-current threshold and a second over-current threshold larger than the first over-current threshold,
 - wherein, when a detection result reaches the first over-current threshold, the control unit performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current while continuously supplying the increased at least one of the voltage and the current to the load, and
 - wherein, when the detection result reaches the second over-current threshold, the control unit stops the operation of the load.
6. An electric power tool comprising:
 - the adapter described in claim **5**;
 - the battery pack; and
 - a tool body having the load.
 7. The electric power tool of claim **6**, wherein the adapter is configured to be provided in the tool body.
 8. The electric power tool of claim **6**, wherein the adapter is configured to be provided between the tool body and the battery pack.
 9. An adapter, comprising:
 - a converter unit configured to increase at least one of a voltage and a current outputted from a battery pack and supply the increased at least one of the voltage and the current to a load;
 - a characteristic detection unit configured to detect a temperature of the battery pack and a current outputted from the battery pack;
 - a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and further perform a control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent an occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection unit; and
 - a storage unit in which temperatures of the battery pack and reference currents corresponding to the temperatures of the battery pack are stored,
 wherein, by referring to a reference current corresponding to the detected temperature of the battery pack, the control unit compares the detected current with the reference current, and performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit when the detected current is higher than the reference current.
 10. The adapter of claim **9**, wherein the control unit performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit within a range equal to or smaller than the corresponding reference value to prevent the occurrence of over-current or over-discharge based on said at least one detection result.
 11. The adapter of claim **9**, wherein the control unit has a first over-current threshold and a second over-current threshold larger than the first over-current threshold,

11

wherein, when a detection result reaches the first over-current threshold, the control unit performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-current, and

wherein, when the detection result reaches the second over-current threshold, the control unit stops the operation of the load.

12. An electric power tool comprising:
the adapter described in claim 9;
the battery pack; and
a tool body having the load.

13. The electric power tool of claim 12, wherein the adapter is configured to be provided in the tool body.

14. The electric power tool of claim 12, wherein the adapter is configured to be provided between the tool body and the battery pack.

15. An adapter, comprising:

a converter unit configured to increase at least one of a voltage and a current outputted from a battery pack and supply the increased at least one of the voltage and the current to a load;

a characteristic detection unit configured to detect at least one of the voltage outputted from the battery pack, the current outputted from the battery pack, and a temperature of the battery pack; and

a control unit configured to control the converter unit to increase each of said at least one of the voltage and the current outputted from the battery pack to a corresponding reference value and further perform a control

12

operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent an occurrence of over-current or over-discharge based on at least one detection result detected by the characteristic detection unit while continuously supplying the increased at least one of the voltage and the current to the load,

wherein the control unit has a first over-discharge threshold and a second over-discharge threshold smaller than the first over-discharge threshold,

wherein, when a detection result reaches the first over-discharge threshold, the control unit performs the control operation of suppressing the increase of said at least one of the voltage and the current in the converter unit to prevent the occurrence of over-discharge while continuously supplying the increased at least one of the voltage and the current to the load, and

wherein, when the detection result reaches the second over-discharge threshold, the control unit stops the operation of the load.

16. An electric power tool comprising:
the adapter described in claim 15;
the battery pack; and
a tool body having the load.

17. The electric power tool of claim 16, wherein the adapter is configured to be provided in the tool body.

18. The electric power tool of claim 16, wherein the adapter is configured to be provided between the tool body and the battery pack.

* * * * *